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Home monitoring of blood glucose by owners of diabetic cats and dogs: technical problems and evaluation of differences between home and hospital blood glucose curves.

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Home monitoring of blood glucose by owners of diabetic cats and dogs: technical problems and evaluation of differences between home and hospital blood glucose curves.

Recently a new method for capillary blood sampling from the ears of dogs and cats using a lancing device (Microlet Vaculence ®, Bayer Diagnostics) has been developed in the Clinic for Small Animal Internal Medicine, University of Zurich.
In the first part of the present study the suitability of this method for use by pet owners and the potential technical problems were evaluated. The owners of seven healthy dogs and seven healthy cats were asked to perform two glucose curves (measuring blood glucose concentration every 2 hours for a total of 12 hours). All dog owners and three cat owners were able to perform a reliable blood glucose curve. The most frequently encountered problems were inadequate formation of blood drop due to excessive digital pressure on the pinna, repeatedly depressing the plunger of the lancing device instead of allowing the negative pressure to slowly build up, and failure to fill the test strip up to the mark. It was concluded that these steps of the procedure need to be stressed during technique demonstration.
In the second part of the study, the objective was to investigate the feasibility of monitoring blood glucose at home in diabetic dogs and cats by owners on a long term basis, the problems encountered and to compare glucose concentrations at home with those measured in the hospital. Owners of 12 diabetic dogs and of 15 diabetic cats were asked to generate 4 glucose curves by means of capillary blood sampling from the ear spaced 3 - 4 weeks apart. Within 1 week after each curve an additional curve was performed in the hospital. Ten dog and 12 cat owners were able to generate blood glucose curves over the study period of 4 months. Most problems were related to generating negative pressure with the lancing device and producing a blood drop, and to restrain the pet. In the majority of cases, these problems could be resolved during the study. Blood glucose concentrations in the clinic tended to be lower than at home. Overall in 42% of

cases in dogs and in 38% of cases in cats, treatment based on hospital curves would have been different than that based on home curves.

The results of these studies demonstrate that the majority of pet owners are able and willing to perform long-term monitoring of blood glucose concentration and that home monitoring of blood glucose concentrations may serve as a new tool in the management of diabetic dogs and cats. It is assumed that glucose measurements at home are more reliable than those measured in the hospital and that home monitoring helps to prevent false treatment decisions.

The work has been published (respectively submitted for publication) in the following journals:

CASELLA M., C.E.REUSCH: Measurement of capillary blood glucose concentrations by pet owners: a new tool in the management of diabetes mellitus. *Journal of the American Animal Association* 2002; 38:239-245.

CASELLA M., C.E.REUSCH: Home monitoring of blood glucose concentration by owners of diabetic dogs. *Journal of Small Animal Practice* 2003; 44:298-305.

CASELLA M., C.E.REUSCH: Home monitoring in cats with diabetes mellitus: evaluation of differences between blood glucose concentrations measured at home and in the hospital. *Journal of Feline Medicine and Surgery* 2003 (submitted for publication)

Measurement of Capillary Blood Glucose Concentrations by Pet Owners: A New Tool in the Management of Diabetes Mellitus

Recently a new method for capillary blood sampling from the ears of dogs and cats was described, which allows the measurement of glucose concentration by means of portable glucose meters. The authors of this report evaluated the suitability of this method for use by pet owners and the potential technical problems. The owners of seven healthy dogs and seven healthy cats were asked to perform two glucose curves (measuring blood glucose concentration every 2 hours for a total of 12 hours). All dog owners and three cat owners were able to perform a reliable blood glucose curve. The most frequently encountered problems were inadequate formation of a blood drop due to excessive digital pressure on the pinna, repeatedly depressing the plunger of the lancet device instead of allowing the negative pressure to slowly build up, and failure to fill the test strip up to the mark. The authors conclude that these steps of the procedure need to be stressed during technique demonstration and that home monitoring of blood glucose concentrations may serve as a new tool in the management of diabetic dogs and cats.

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Introduction

Determination of blood glucose concentrations and serial blood glucose curves are important aspects of long-term management of diabetic dogs and cats. These measurements are used to assess insulin efficacy, the glucose nadir, and the duration of effect of insulin, thereby serving as a basis for modifications in insulin therapy.[1-4]

Historically, blood collection for determination of glucose concentration has been performed predominantly by a veterinarian, because owners are not skilled at venipuncture. However, this is time consuming and expensive for the owner and may affect the blood glucose concentration, as the pet may be stressed in an unfamiliar environment and be reluctant to eat.[5,6]

In contrast, many human diabetics perform home monitoring of blood glucose concentrations using a portable blood glucose meter (PBGM) and capillary blood, which is collected by pricking a fingertip with a lancet device.[7,8] It has been determined that home monitoring of blood glucose concentrations by human diabetics results in optimization of metabolic control.[9] However, it has also been shown that problems related to blood collection and incorrect use of the PBGM do occur with home monitoring. This can result in erroneous blood glucose measurements, undue changes in treatment, and loss of motivation of the patient.[10] Thus, basic training followed by periodic reassessment of the technique is of utmost importance.[11-17]

In a recent study, the authors demonstrated the feasibility of the collection of capillary blood from dogs and cats using a lancet device designed for humans.[18] In all animals, enough blood from the inner

aspect of the ear was collected by the same veterinarian for determination of blood glucose concentration using a PBGM. In addition, it was shown that there was good agreement between the glucose concentration of capillary blood and that of venous blood.[18] The results of this study suggested that this technique may be suitable for use at home by owners of diabetic companion animals.

The goals of the present study were to evaluate whether pet owners are able to collect capillary blood and perform glucose measurements at home, and to investigate what types of technical problems may arise during these procedures.

Materials and Methods

Animals

The animals used were client owned and consisted of seven healthy dogs and seven healthy cats. The dogs ranged in age from 2 to 10 years (median, 5 years) and were comprised of five spayed females and two intact males. The cats ranged in age from 6 months to 10 years (median, 2 years) and were comprised of three spayed females, three castrated males, and one intact male. Animals were chosen for inclusion into the study when owners were unfamiliar with any kind of blood collection but were willing to learn capillary blood sampling. The study was approved by the veterinary authorities of the Canton of Zurich.

Study Design

In all animals, the results of clinical, hematological, and serum biochemical evaluations were within reference ranges. The methods for collection of capillary blood from the ear using a lancet device and measurement of blood glucose concentration using a PBGM were both explained and demonstrated to the pet owners individually. The owners then performed one or two blood collections with the clinician present. The entire instruction lasted about 30 minutes. The owners were then given a lancet device,[a] a PBGM,[b] two forms for recording blood glucose concentrations, and two questionnaires assessing owner experience with the technique. They were asked to perform two blood glucose curves by determining the blood glucose concentration every 2 hours for a total of 12 hours (i.e., consisting of seven blood collections). The second blood glucose curve was performed 1 to 2 weeks after the first. The days on which the first and second blood glucose curves were determined were designated as days 1 and 2, respectively. The blood glucose measurements were recorded, and the questionnaire was filled in after each blood glucose curve. Those owners who were not able to collect blood at home received a second instruction in the clinic.

Blood Collection and Blood Glucose Concentration Measurement Technique

This technique has been previously described[19] and is shown in Figure 1. Briefly, the tip of the ear was held between the thumb and index finger (it was left to the discretion of the owner as to which ear pinna to use), and the entire surface of the outer pinna was held flat using the remaining fingers of the same hand. With the other hand, the lancet device was lightly placed on a nonhaired area of the pinna so that an airtight seal was formed between the endcap of the device and the skin. When the plunger cap of the instrument was pressed, a lancet moved quickly back and forth once. Pressure between the endcap and the skin was maintained while the plunger was slowly released. The skin of the ear began to slightly bulge up into the endcap, because of the developing negative pressure. The formation of a drop of blood was hastened by releasing the pressure that was exerted on the surface of the pinna by those fingers holding the pinna in a flat position. When an adequate amount of blood appeared on the skin, which was visible through the transparent endcap, the plunger was pressed down to release the negative pressure, and the lancet device was removed. Then the test strip in the PBGM was brought into contact with the blood drop, and the required amount of blood was automatically drawn onto the test strip. The concentration of blood glucose was shown on the PBGM display 29 seconds later. The owners were instructed to warm the ear by rubbing it or to change the lancet in the lancet device when an insufficient amount of blood was obtained. Usually the same lancet was used to perform a blood glucose curve (i.e., for seven blood glucose measurements); the lancet was cleaned in between when needed.

The PBGM was calibrated before it was given to the owner, and further calibration during the study was deemed unnecessary. The owners were shown how to perform a control measurement with a control test strip and were encouraged to do this prior to the blood glucose curve on each day.

Questionnaire

There were a total of 18 questions divided into seven sections that related to the following aspects of blood collection and glucose measurements: restraint of the animal, generation of a vacuum with the lancet device, generation of a drop of blood, absorption of blood onto the PBGM test strip, overall use of the equipment, patient tolerance of the procedure, and judgment regarding its feasibility.

Statistical Analysis

All results were analyzed by means of parameter-free statistical methods.[c] Ranges and median values are given. The Mann-Whitney-U-Test was used to determine differences. Differences were considered significant at $P<0.05$.

Results

Dogs

Four of the seven owners completed both blood glucose curves without additional instruction. One of these four owners reported having no problems during the entire study. The problems encountered most frequently by the other three owners were generation of negative pressure with the lancet device (n=2), generation of a drop of blood

Figures 1A-1D—Blood collection technique. **(1A)** The tip of the ear is held between the thumb and index finger, and the surface of the pinna is held flat by the rest of the fingers. Then the lancet device is set on a nonhaired area of the ear. **(1B)** An airtight seal between the device and ear is obtained by pushing the outer ear against the device with the tip of one finger. **(1C)** The lancet is activated by pressing the plunger cap of the device. With slow release of the plunger cap, a negative pressure is created, and the skin slightly bulges up into the endcap. The negative pressure is maintained until there is an adequate amount of blood. **(1D)** The portable blood glucose meter (PBGM), with the test strip inserted, is placed over the drop of blood. The blood is automatically absorbed, and after 29 seconds the blood glucose concentration is displayed.

(n=2), and handling of the PBGM (n=1). However, after repeated attempts they were able to overcome these difficulties on their own. The remaining three owners were unable to obtain a blood glucose measurement on the first day because of technical problems, which included inability to generate negative pressure with the lancet device (n=1) and inadequate absorption of the blood drop (n=2). The problem with the generation of negative pressure was due to incorrect use of the lancet device. Instead of allowing the negative pressure to slowly build after depressing and releasing the plunger once, this owner had repeatedly depressed the plunger. Additionally, the negative pressure was inadequate because the owner failed to reduce the pressure exerted by the fingers on the surface of the pinna. The problem with the absorption of the blood drop was due to the erroneous attempt to drop the blood onto the test strip rather than allowing the blood to be absorbed automatically by the strip. This resulted in an inadequate amount of blood for correct measurement by the PBGM. Additional technical problems that were experienced by those owners who were unable to obtain a measurement on day 1 were failure to produce an adequate amount of blood (n=1) and inadequate restraint of the dog (n=1). The problems were identified during a second consult. After the technique was explained and demonstrated a second time, these three owners were able to perform the second blood glucose curve without difficulty.

With respect to the whole group, patient resistance to the blood collection technique was shown on day 1 during generation of a negative pressure (n=4), lancing of the skin (n=3), and restraint (n=1). On day 2, less negative reactions were recorded; they appeared during generation of a negative pressure (n=3) and lancing of the skin (n=1). Generally, the dogs tolerated the procedure well. On day 1, a second person was required to restrain three of the dogs, whereas

Table 1

Technical Problems During the Determination of Blood Glucose Concentration in Seven Dogs

	Incidence of Technical Problem*							
	Never†		Sometimes‡		Often§		Always\	
Technical Problem	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
1. Restraint required	4	3	2	3	-	-	1	1
Repeated punctures required	3	4	3	2	1	1	-	-
Resistance to procedure	2	3	4	3	-	-	1	1
2. Vacuum generation	-	2	2	3	4	2	1	-
Repeated punctures required	-	2	5	5	2	-	-	-
Accidental repeated punctures	7	7	-	-	-	-	-	-
3. Blood drop generation	-	4	2	3	4	-	1	-
Warming of the ear required	3	3	1	2	1	1	2	1
Changing of lancet required	7	7	-	-	-	-	-	-
4. Absorption of blood drops	2	5	3	2	-	-	2	-
5. Portable blood glucose monitor handling	3	5	3	2	1	-	-	-
Test strips handling	3	5	4	2	-	-	-	-

* It is possible that a given owner experienced more than one technical problem simultaneously. This explains the discrepancy between the numbers in the text and those in the tables. The sum for each step was not always seven, because some owners were unable to complete all steps of the procedure. For example, for generation of a negative pressure in cats, two owners were unable to complete this step and thus, the reported number is five (see Table 3).

† Never=problem did not occur during sampling

‡ Sometimes=problem occurred two or three times per sampling

§ Often=problem occurred more than three times per sampling

\ Always=problem occurred each time when sampling was tried

the other four owners were able to collect blood and operate the PBGM alone. Two of the latter reported having minor problems with the restraint of their dogs. On day 2, a second person was required to restrain one dog only. The incidences of technical problems encountered in dogs are reported in Table 1.

Operation of the PBGM generally was not a problem for owners. Four had difficulty coordinating the positioning of the ear and placing the test strip in the PBGM to allow absorption of the blood onto the test strip. The control measurements were performed without difficulty by all of the owners prior to the blood glucose curve on each day; the results were always within the reference range. Overall procedure assessment is provided in Table 2.

Cats

Two of the seven owners were able to perform both blood glucose curves without additional instruction. One other owner was unable to perform the first blood glucose curve. The problem was due to insufficient generation of negative pressure because of incorrect use of the lancet device (repeated depression of plunger as in the above-mentioned dog). However, after the procedure was explained and demonstrated a second time and the help of a second person was obtained to restrain the cat, this owner completed the second blood glucose curve.

The procedure could not be performed by the remaining four owners. Two of the four cats resisted restraint throughout the entire study, and blood could not be collected for any blood glucose determination. This was attributed to poor tolerance of the procedure, even with a second person's help in restraining the animal. The other two of the four cats tolerated collection of blood only sporadically, so a complete blood glucose curve was not possible. In one of those two cases, bilateral aural hematomas developed, which made the generation of a blood drop impossible. The second cat became fractious after several unsuccessful attempts to collect blood and subsequently did not tolerate the procedure. Additional problems encountered by these two cat owners included inability to generate negative pressure using the lancet device (n=1) and inability to obtain an adequate amount of blood (n=1).

Table 2

Blood Collection and Blood Glucose Concentration Measurement; Owner Evaluation of Feasibility of the Procedure

	Grading Frequency			
	Dog		Cat	
Evaluation Grade	Day 1	Day 2	Day 1	Day 2
Good	1	1	-	2
Slightly difficult	1	6	2	1
Difficult	2	-	-	-
Not feasible	3	-	5	4

Note: The grading was done subjectively by the owners.

Repeated instruction and demonstration of the procedure did not aid the four cat owners who were unsuccessful in performing a blood glucose curve.

With respect to the whole group, patient resistance to the blood collection technique appeared during restraint (n=4), lancing of the skin (n=4), and generation of a negative pressure (n=2) on day 1. On day 2, there was no improvement in the demeanor of the cats during the procedure. Operation of the PBGM and test strips generated few problems for the cat owners. As well, the control measurements were performed once daily without difficulty; all measurements were within the required range. Overall procedure evaluation in the cats studied and incidence of technical problems are provided in Tables 2 and 3, respectively.

Glucose Measurements

A total of 77 blood glucose measurements were done in dogs, and 35 were done in cats. In four instances (four different animals: two dogs and two cats), the PBGM registered "lo" (low, <1.1 mmol/L), which was attributed to an insufficient amount of blood. In the dogs studied, the blood glucose concentrations obtained during glucose curves ranged between 1.9 and 5.4 mmol/L (median, 3.7 mmol/L). Three (3/77, 4%) glucose measurements were <2.8 mmol/L (1.9 mmol/L [n=2], 2.2 mmol/L [n=1]).

In the cats of this study, the blood glucose concentrations obtained during glucose curves ranged between 1.8 and 4.1 mmol/L (median, 3.3 mmol/L). Three (9%) measurements were <2.8 mmol/L (1.8 mmol/L, 2.6 mmol/L, 2.7 mmol/L). Glucose concentrations were evaluated statistically in those six animals (four dogs and two cats) in which both glucose curves were obtained. There was no statistically significant difference between days 1 and 2.

Discussion

The concept of home monitoring of blood glucose concentration in dogs and cats stemmed from the experience in human medicine where it has gained wide acceptance in the management of diabetic individuals. The collection of capillary blood from the ear of diabetic dogs and cats and the measurement of blood glucose concentration with a PBGM are performed routinely in the authors' clinic to determine blood glucose curves. Previous studies have shown that there is good correlation between the glucose concentrations of capillary and venous blood.[18] For the majority of veterinarians and veterinary students, the procedure is easy and quick to perform. An adequate amount of blood can be obtained relatively easily with the lancet device used because of the negative pressure created by the device.[18] The results of this study indicate that this is also true for dog owners and some cat owners.

Recent studies have evaluated a variety of different PBGMs.[19-21] The results obtained by them are reasonably close to those obtained with reference methods, although some devices are more accurate than others.[19-21] For this study, the authors decided to use the Glucometer Elite PBGM for several reasons. First, it has been shown in the authors' previous studies that blood glucose values obtained by this PBGM are reasonably close to reference methodology.[20,21] Second, in contrast to other PBGMs, which may over- and underestimate the glucose concentrations, the Glucometer Elite almost always slightly underestimates them. Therefore, deviations from the reference values are more calculable than those of other PBGMs.[20,21] Third, in the authors' experience, the Glucometer Elite is the easiest PBGM to use, as it has no buttons to press, it turns on automatically when the test strip is inserted, and it requires only a small amount of blood.[18,20,21]

To the authors' knowledge, there are no studies that have investigated the use of home monitoring of blood glucose concentrations of dogs and cats by their owners and the associated potential problems. When instructing the owners, it is important to stress that an adequate amount of blood is needed for the PBGM to measure the glucose concentration

Table 3

Technical Problems During the Determination of Blood Glucose Concentration in Seven Cats

	Incidence of Technical Problem*							
	Never†		Sometimes‡		Often§		Always\	
Technical Problem	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
1. Restraint required	1	1	1	3	1	-	4	3
Repeated punctures required	-	1	2	2	-	-	3	1
Resistance to procedure	-	-	3	4	-	1	4	2
2. Vacuum generation	2	3	2	1	-	-	1	-
Repeated punctures required	1	2	-	-	1	1	3	1
Accidental repeated punctures	4	4	1	-	-	-	-	-
3. Blood drop generation	-	3	-	1	4	-	1	-
Warming of the ear required	3	3	1	-	-	-	1	1
Changing of lancet required	5	4	-	-	-	-	-	-
4. Absorption of blood drops	3	4	1	-	-	-	-	-
5. Portable blood glucose monitor handling	2	3	2	1	-	-	-	-
Test strips handling	2	3	1	1	1	-	-	-

* See comments from Table 1.
† Never=problem did not occur during sampling
‡ Sometimes=problem occurred two or three times per sampling
§ Often=problem occurred more than three times per sampling
\ Always=problem occurred each time when sampling was tried

correctly. The authors theorize that this was the explanation for those cases in which the PBGM registered "lo." Additionally, blood glucose levels were unexpectedly low (<2.8 mmol/L) in six instances. Previous studies have revealed that a weak point in the measuring procedure using the Glucometer Elite is that an insufficient amount of blood may result in inaccurate, low readings without giving an error message.[19,20] Therefore, the authors are unable to tell if those readings of <2.8 mmol/L were due to a handling error or due to truly low blood glucose concentrations. Recently, the new generation of Glucometer Elite has been marketed; this PBGM requires even less blood; therefore, it seems that this potential problem can be minimized in the future.

In this study, there was a clear difference between the results of dogs and cats. Most of the dog owners reported that their pet tolerated blood collection well. All of the dog owners reported that their technique for blood collection and use of the PBGM improved quickly and that this led to an increased confidence in the results. In contrast, only three of seven cat owners were able to perform one or both blood glucose curves. These owners also reported that the procedure became easier to perform after they had gained some experience. The owners also found that the cats were more tolerant of blood collection when they were placed in a favorite spot, such as a windowsill or bed. Interestingly, the two cats that readily tolerated the procedure were the only indoor cats of the group. In four of the seven cats, no blood curve was obtained. For these four cat owners, further technical support from their veterinarian did not help, because the errors were not of a procedural nature. The problems that were encountered in three of the four cats were attributed entirely to their disposition. In the fourth case, bilateral aural hematomas developed, which were probably attributable to the delicate ear structure of this breed (i.e., Devon rex). Similar lesions did not occur in any of the other cats or dogs. In fact, the sites of blood collection were barely visible and not painful. In contrast to the dogs, the cats did not become accustomed to the procedure. With one exception, the collection of blood from cats was either well tolerated from the start or not tolerated at all.

It is important that owners of diabetic dogs or cats doing home monitoring have ready access to veterinary support, if required. Ten of 14 owners called for advice one or more times, particularly on day 1. Some had specific questions regarding the procedure, while others wanted reassurance that they were performing the procedure correctly. After day 1, two dog owners were discouraged to the point that they did not want to continue. However, after deliberate dis-

cussion, they went on to complete the blood glucose curves without further problems. When support via telephone did not suffice, owners were given additional detailed explanations and demonstrations at home or in the clinic. The latter was ideal for immediate identification and correction of errors. At the end of the study, all of the dog owners said that they would perform this procedure on a regular basis if they had a diabetic animal. Three owners commented that without the extra motivation and support, which allowed them to successfully complete the second blood glucose curve, they would have decided differently. As expected, only three of the cat owners said they would perform this procedure on a regular basis; these were those owners who were able to complete one or both blood glucose curves.

The prerequisite for good owner instruction is that the veterinarian himself is able to perform the procedure correctly and that he is aware of all potential sources of errors. According to the authors' results, the most frequently encountered problems were inadequate formation of a blood drop due to excessive pressure with the finger on the pinna during use of the lancet device, repeatedly depressing the plunger of the lancet device instead of allowing the negative pressure to slowly build up, and failure to fill the blood glucose test strip up to the mark. These steps of the procedure need to be stressed and better clarified during both the explanation and demonstration of this technique. Frequent reassessment of the technique will also increase both owner and veterinarian confidence in the results generated.

Home monitoring of blood glucose concentration in human diabetics has been performed for many years and has become the foundation to proper treatment of diabetics.[22] The American Diabetes Association recommends home monitoring of blood glucose concentrations as an essential part of the management of diabetes mellitus.[14,15] However, it has long been known that many errors can occur during home monitoring of blood glucose concentrations in humans. The National Steering Committee for Quality Assurance in Capillary Blood Glucose Monitoring[12] emphasized the importance of patient education with repeated demonstration of the procedures and observation of the patients as they perform them. They recommended reassessment of the technique 30 and 180 days after training and yearly thereafter, or sooner when results indicate possible procedural error. These recommendations should be implemented if home monitoring of blood glucose concentrations is to be successful in diabetic dogs and cats.

The results of this study identified important causes of error in collection of capillary blood from the ear and in the use of the PBGM. The authors have been able to use these results for better education of owners who want to perform home monitoring of blood glucose concentrations in diabetic dogs and cats. Further studies are in progress to determine whether home monitoring of blood glucose concentrations improves the glycemic control of diabetic dogs and cats.

[a] Microlet Vaculance; Bayer Diagnostics, Zurich, Switzerland
[b] Glucometer Elite; Bayer Diagnostics, Zurich, Switzerland
[c] SPSS/PC V 6.0, Base manual; SPSS Inc., Chicago, IL 1993

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Home monitoring of blood glucose concentration by owners of diabetic dogs

The objective of this study was to investigate whether home monitoring of blood glucose of diabetic dogs by owners would be possible on a long-term basis. The owners of 12 diabetic dogs were each asked to generate four glucose curves by taking capillary blood samples from their dog's ear, at three- to four-week intervals. Within one week of each curve being produced by the owner, an additional curve was produced by a veterinarian in the hospital. Ten owners were able to generate blood glucose curves; three of them needed a second demonstration, and two telephoned for further guidance. The blood glucose concentrations obtained from the first two 'hospital' curves were significantly lower than those measured at home. Overall, in 42 per cent of cases, the treatment based on the hospital curves would have been different from that based on 'home' curves. The results of this study indicate that the majority of owners were able and willing to perform long-term monitoring of the blood glucose concentrations of their dogs.

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INTRODUCTION

In diabetic dogs and cats, measurement of blood glucose concentrations and generation of blood glucose curves are important elements of glycaemic control (Feldman and Nelson 1996). Many human diabetics practise self- or home monitoring, which means that they determine blood glucose concentrations themselves (Cohen and Zimmet 1980, Bergman and Felig 1984, American Diabetes Association 1996, 1998, Foster and others 1999). Blood is usually collected from a finger tip using an automatic lancing device, and blood glucose concentration is measured using a portable blood glucose meter (PBGM) (Baum 1996, Girouard and others 2000). It has been claimed that the ability of patients to perform frequent and simple measurements with a PBGM is the most significant advance in the management of diabetes since the discovery of insulin (Watts and Keffer 1989).

In the past few years, a number of studies have investigated the feasibility of home monitoring of blood glucose concentrations in diabetic dogs and cats. Recently, a method for collecting capillary blood from the ear of dogs and cats using an automatic lancing device was reported (Wess and Reusch 2000a). In addition, it was shown that glucose concentrations of capillary blood from the ear correspond with those of venous blood (Wess and Reusch 2000a). Evaluation of various PBGMs showed that their accuracy and reliability were sufficient for the purpose of home monitoring (Wess and Reusch 2000b,c). Another recent study demonstrated that dog and cat owners who had no previous experience of blood collection and determination of blood glucose concentrations, were able to reliably master these procedures (Casella and Reusch 2000).

Until recently, home monitoring was not routinely performed by owners of diabetic animals. Thus, the aims of this prospective study were: to determine whether owners of diabetic dogs were willing and able to perform home monitoring on a long-term basis, and to assess what problems were encountered; to compare the results of home and hospital blood glucose curves; and to compare treatment decisions based on home- and hospital-generated blood glucose curves.

MATERIALS AND METHODS

Selection of dogs

The study was conducted between 1999 and 2000 at the Clinic for Small Animal Medicine, University of Zurich, Switzer-

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The Royal College of Veterinary Surgeons considers that the taking of a blood sample from an animal is an act of veterinary surgery. It may lawfully be done in the UK by veterinary surgeons or veterinary nurses, and by the owners of farm animals, but the owners of small animals only have power to give them minor medical treatment.

land. Dogs with diabetes mellitus were included in the study if owners were willing to learn home monitoring techniques, and to return to the hospital for six re-evaluations of their dog's glucose concentration, over a 16-week period.

Diagnosis of diabetes mellitus was based on characteristic clinical signs, which included polyuria, polydipsia, polyphagia, weight loss, fasting hyperglycaemia and elevated serum fructosamine (>340 µmol/litre). Twelve dogs aged from five to 13 years (median nine years) and ranging in weight from 5·1 to 32·0 kg (median 15·5 kg) were used in the study. Nine dogs had recently been diagnosed with diabetes mellitus and three had been treated with insulin for between two weeks and two months before the commencement of the study. There were seven female (all spayed) and five male (two castrated) dogs. Among the breeds represented were poodle (three), Labrador retriever (2), cocker spaniel (two), Eurasian (one), Border collie (one), Bergamasker (one), dachshund (one), and one mixed-breed dog. None of the owners were familiar with blood collection prior to the study. Informed owner consent was obtained in all cases.

Study design

Diabetes mellitus was diagnosed in nine dogs in the authors' clinic and in three dogs by referring veterinarians. A thorough physical examination, complete blood count (CBC), biochemical profile (including fructosamine concentration) and urinalysis were performed for all dogs. Further examinations were performed when necessary. All dogs received 0·3 to 0·7 IU/kg of an intermediate-acting insulin (Insulin Novo Lente MC 40; Novo Nordisk, Küsnacht, Switzerland [11 dogs] and Caninsulin; Intervet Boxmeer, the Netherlands [one dog]), subcutaneously twice daily. The majority of dogs remained in the authors' clinic for two days. Blood glucose concentrations were determined before the administration of insulin and then every two hours for a 12-hour period (seven measurements in total). The dosage of insulin was adjusted only when hypoglycaemia occurred (blood glucose concentration <4 mmol/litre). Two dogs that had diabetic ketoacidosis at the time of admission underwent intensive care treatment; after stabilisation they were treated with an intermediate-acting insulin at the above-mentioned dosage. At discharge, owners received detailed information on various aspects of diabetes mellitus and were taught how to inject the insulin. The concept of home monitoring was introduced for the first time at this stage.

Re-evaluations were scheduled for one, three, six, nine, 12 and 16 weeks after the first evaluation and included a detailed history, physical examination, determination of haematocrit values and concentrations of serum fructosamine, albumin and total protein, and the creation of a blood glucose curve. This involved the measurement of blood glucose concentrations before the administration of insulin and then every two hours for a 12-hour period. The dogs were fed their usual diet.

At the second re-evaluation (three weeks after the first examination), each owner was taught how to monitor their dog's glucose levels at home. This process took a minimum of 30 minutes and consisted of repeated demonstrations of the use of the lancing device and the PBGM. The owner then performed the technique once or twice on his or her dog. Each owner was also taught how to calibrate the PBGM and check its accuracy using the control strip, and how to record

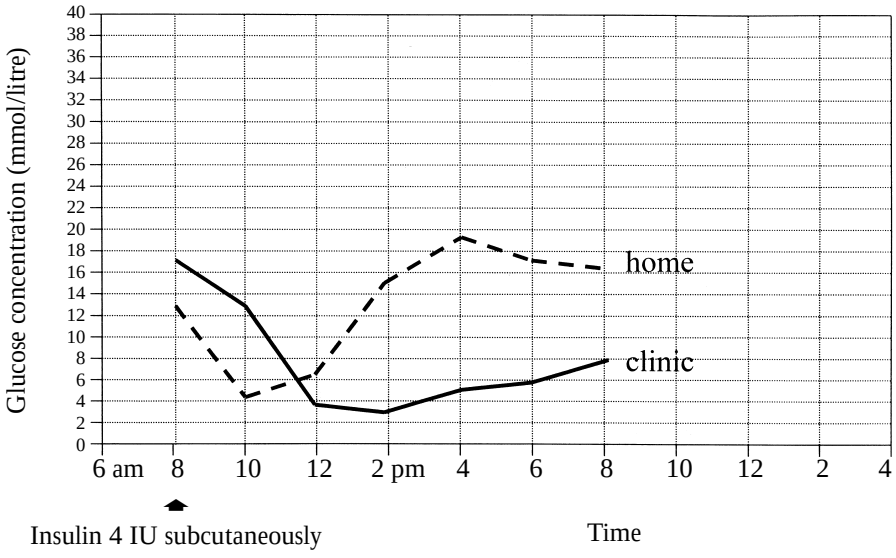


FIG 1. Form on which owners recorded the blood glucose concentrations of their diabetic dogs. This example shows the home blood glucose curve (broken line) and the hospital blood glucose curve (solid line) from a diabetic, seven-year-old, 5·7 kg, spayed female poodle. The dog received 4 IU of an intermediate-acting insulin twice daily. For each blood glucose curve, the concentration of blood glucose was measured before the administration of insulin and then every two hours for a 12-hour-period. The two blood glucose curves, which were determined within one week of each other, differ. The home blood glucose curve has a nadir of 4·6 mmol/litre, which is considered good; however, it shows that the efficacy of the insulin is too short (effect lasts until 1 pm). The hospital blood glucose curve has a nadir of 2·8 mmol/litre, which is too low, and the efficacy of the insulin is long (insulin effect lasts beyond the time of the next injection). Based on the home blood glucose curve, a longer-acting insulin would be required, but based on the hospital curve, a reduction in the insulin dosage would be needed. No change in treatment was made at this point. The next two home blood glucose curves had a nadir of 7·5 and 8·9 mmol/litre. The insulin dosage was increased by 1 IU, and the polyuria/polydipsia, which was present at the time of the previous curve, resolved. The low glucose nadir and long efficacy of the insulin in the previous hospital blood glucose curve were attributed to decreased appetite of the dog while in the hospital

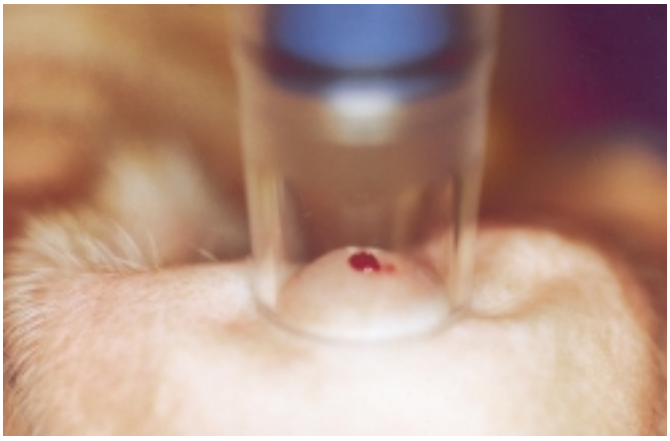


FIG 2. Generation of a drop of blood from the inner pinna of a diabetic dog using negative pressure created by a Microlet Vaculance. Generation of negative pressure is a critical part of blood collection from the ear and can pose a variety of technical problems. It is important to place the lancing device flat on the inner pinna and to avoid excessive pressure from the outer pinna. An error often made by owners when first using the lancing device is to repeatedly depress the plunger, thereby dissipating the negative pressure rather than allowing it to build up

blood glucose concentrations on the prepared forms (Fig 1).

The owners received written instructions, including photographs, of how to cary out the home monitoring; a PBGM, test strips, a lancing device, a chart on which to record blood glucose measurements, and a questionnaire. They were asked to produce a blood glucose curve at home within one week of the next re-evaluation. They were advised that blood glucose concentrations should be determined before the administration of insulin and then every two hours afterwards for a 12-hour period (seven measurements). Owners were also asked to fill out a questionnaire after producing each blood glucose curve. At the third re-evaluation (six weeks after the first evaluation), a veterinarian (M. C.) evaluated and, if necessary, corrected the owner's technique of capillary blood collection. When required, other aspects of the home monitoring technique were also evaluated at this time.

Insulin dosage was adjusted based on the glucose nadir: when the nadir was <4 mmol/litre, ≥4 and <10 mmol/litre, or ≥10 mmol/litre, the insulin dosage was decreased, unaltered or increased, respectively. Based on the glucose curves, feeding times and the timing and duration of exercise were adjusted in some dogs. In most cases, these decisions were based on the blood glucose curves derived at the owner's home.

Owners produced a total of four blood glucose curves each, which were referred to as home curves. A blood glucose curve was produced in the authors' hospital within one week of each home curve being produced; these curves were referred to as hospital curves. Each of the four home curves was compared to the corresponding hospital curve. The comparisons were referred to as the first curve comparison (weeks 5 and 6 after first evaluation), second curve comparison (weeks 8 and 9 after first evaluation), third curve comparison (weeks 11 and 12 after first evaluation), and fourth curve comparison (weeks 15 and 16 after first evaluation). The dosage of insulin administered to the dog was identical for each of the curves that were compared.

Equipment

The PBGM used in this study was a Glucometer Elite and the lancing device was a Microlet Vaculance (both Bayer Diagnostics, Zurich, Switzerland).

Collection of capillary blood and measurement of blood glucose concentration

Capillary blood collected from the inner pinna using a lancing device was used for all blood glucose determinations (Wess and Reusch 2000a). All blood glucose concentrations were measured using a PBGM (Fig 2).

Questionnaire

The owner's questionnaire contained a total of 18 questions which related to the following aspects of blood collection and glucose measurement: restraint of the dog, generation of negative pressure with the lancing device, generation of a drop of blood, absorption of blood, use of equipment, the dog's tolerance of the procedure, and opinion on the overall feasibility of the procedure (Casella and Reusch 2000).

Statistical analysis

A descriptive data analysis was used for describing technical problems encountered during blood collection. Range and median were used for the ages and weights of the dogs. All blood glucose curve data were analysed using analysis of variance (ANOVA) for repeated evaluations (StatView 5·0; SAS Institute, Wangen, Switzerland). Differences were considered significant when $P<0{\cdot}05$.

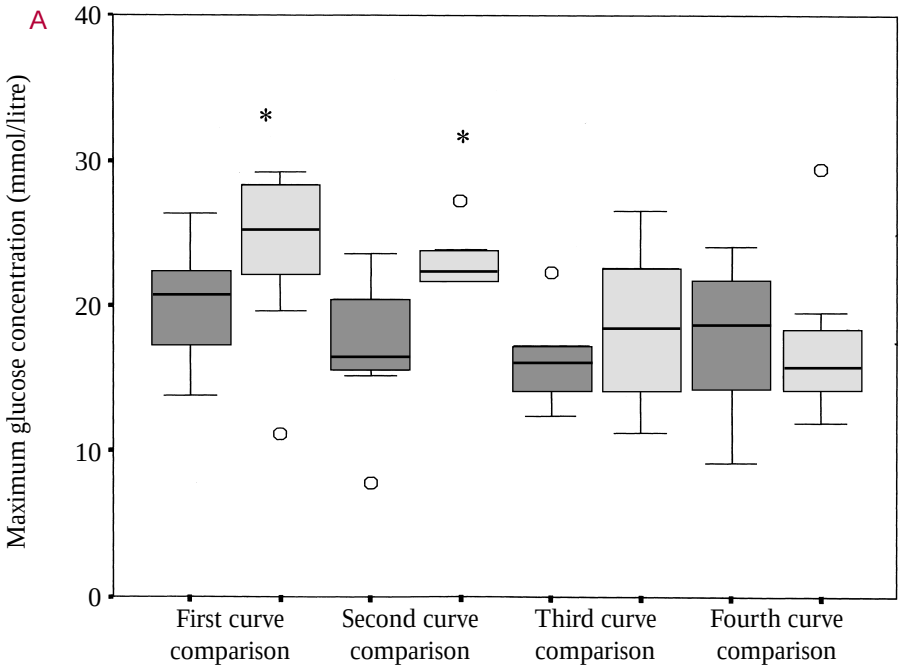
RESULTS

Clinical signs and serum fructosamine

Clinical signs of diabetes mellitus rapidly improved during the treatment period. At the end of the study, 10 owners felt that their dogs were normal and two felt that their dogs had shown a marked improvement. Serum fructosamine concentrations decreased during treatment in nine dogs; remained unchanged in two, and increased in one. Compared with the initial concentration, serum fructosamine was significantly decreased by the time of the first curve comparison (six weeks after the first evaluation).

Feasibility of home monitoring

Ten out of the 12 owners were able to deter-



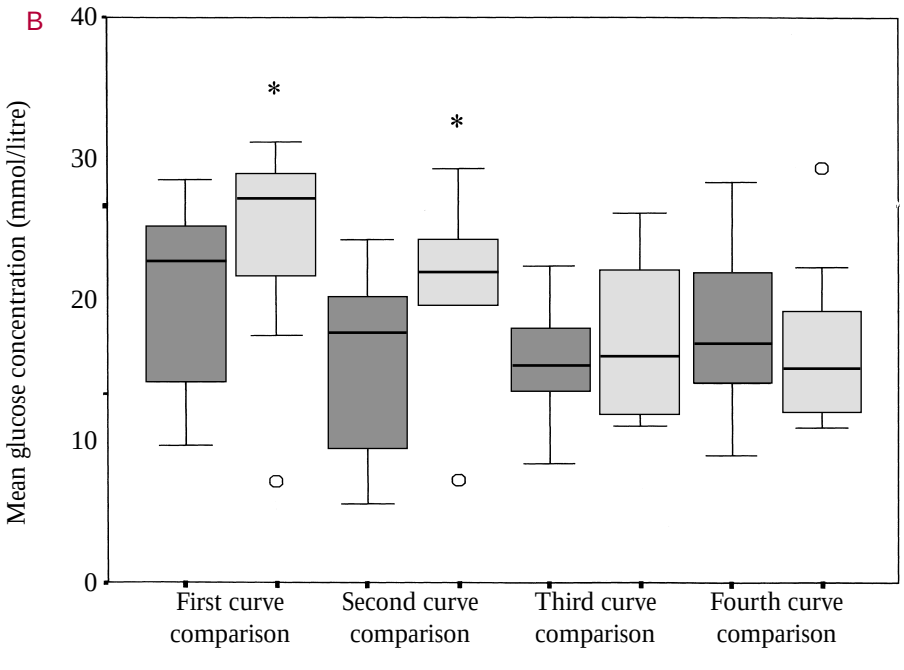


FIG 3. Box and whiskers plots comparing (A) maximum blood glucose concentrations from home and hospital blood glucose curves produced from 10 diabetic dogs, and (B) mean blood glucose concentrations from home and hospital blood glucose curves. The horizontal lines of the box represent, from bottom to top, the 25th, 50th (median) and the 75th percentiles. The ends of the whiskers represent the 10th and the 90th percentiles. Outlying data points are represented by open circles. The maximum and mean blood glucose concentrations of the first and second hospital blood glucose curves were significantly lower than those of the first and second home curves. *P<0·05

mine their dog's blood glucose concentrations. Eight of the 10 owners completed all four blood glucose curves and two encountered problems with blood collection initially, but completed the last three blood glucose curves successfully. Two out of the 12 owners were unable to perform any blood glucose measurements because their dogs did not tolerate the procedure.

Problems encountered initially by owners included: producing the required negative pressure with the lancing device (8/10), restraint of the dog (5/10), producing a drop of blood (4/10), absorption of the drop of blood (4/10), and correct use of the test strips (2/10) and the glucometer (2/10). However, after practice and with repeated advice from a veterinarian, most of these problems were resolved quickly. At the end of the study, there were still a few minor problems involving the production of negative pressure using the lancing device (3/10), production of a drop of blood (1/10), and restraint of the dog (1/10).

Of the 10 owners, home monitoring at the time of the first curve comparison was considered not feasible for two, difficult for one, mostly straightforward for three, and straightforward for four. At the end of the study, this had changed to mostly straightforward for one owner and straightforward for nine. Nine out of the 10 owners performed blood glucose measurements alone and one owner required another person to assist for the first three curves. Of the 10 dogs, five tolerated the procedure very well from the start of the study, four became accustomed to the procedure during the first day, and one did not tolerate the procedure for the first blood glucose curve.

Comparison of home and hospital blood glucose curves

A total of four comparisons between home and hospital blood glucose curves were made. The maximum (±SD) blood glucose concentrations (mmol/litre) in blood glucose curves performed in the authors' hospital and at home, respectively, were

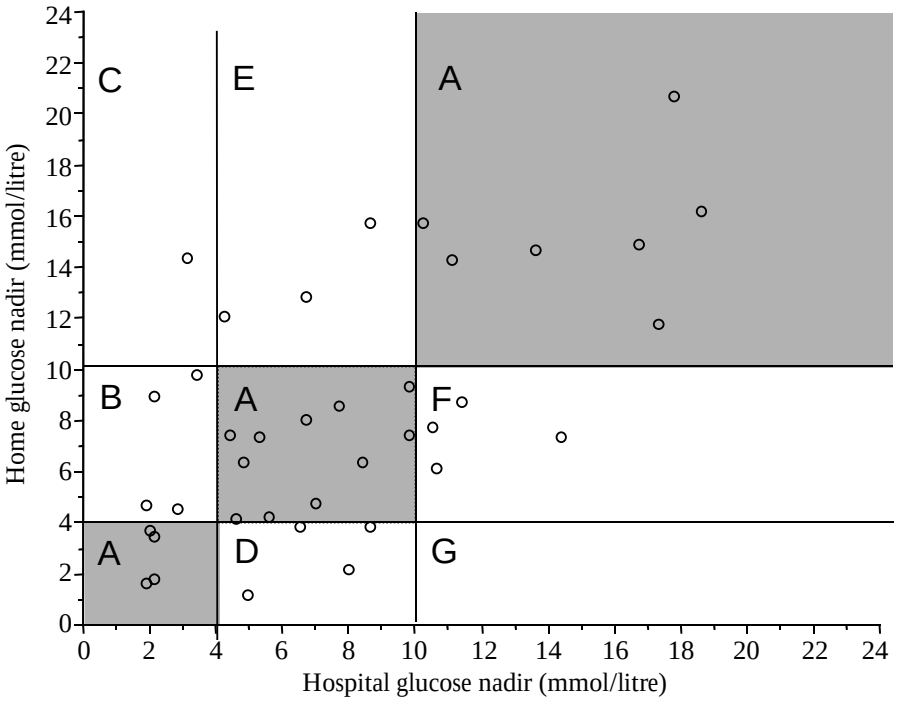


FIG 4. Graphic representation of the glucose nadirs determined in all blood glucose comparisons. The x-axis represents the nadirs determined in the hospital blood glucose curves and the y-axis represents the nadirs of the home blood glucose curves. For 22 of 38 blood glucose pairs, the decisions regarding treatment were in agreement (zone A). For 16 of 38 pairs, the decisions regarding treatment, based on the two curves, would have differed, as follows:
zone B: hospital curve, insulin dosage decreased; home curve, insulin dosage unchanged
zone C: hospital curve, insulin dosage decreased; home curve, insulin dosage increased
zone D: hospital curve, insulin dosage unchanged; home curve, insulin dosage decreased
zone E: hospital curve, insulin dosage unchanged; home curve, insulin dosage increased
zone F: hospital curve, insulin dosage increased; home curve, insulin dosage unchanged

18·9 ±4·5 and 24·0 ±5·9 for the first curve comparison; 15·8 ±5·5 and 21·8 ±6·7 for the second curve comparison; 15·2 ±3·3 and 17·8 ±5·4 for the third curve comparison; and 18·5 ±6·5 and 18·9 ±6·9 for the fourth curve comparison. The mean (±SD) glucose concentrations (mmol/litre) of curves performed in the authors' hospital and at home, respectively, were 13·7 ±4·9 and 18·1 ±6·0 for the first curve comparison; 11·0 ±5·0 and 15·7 ±6·0 for the second curve comparison; 10·4 ±3·1 and 12·5 ±4·2 for the third curve comparison; and 13·5 ±5·4 and 13·0 ±4·9 for the fourth curve comparison. The nadirs (±SD) of the hospital and home curves, respectively, were 9·2 ±5·5 and 11·7 ±6·4; 6·9 ±3·4 and 7·6 ±4·3; 5·3 ±2·8 and 7·4 ±3·2; and 8·5 ±5·1 and 7·3 ±4·7 for the first, second, third and fourth curve comparisons, respectively.

For the first and second curve comparisons, the maximum and mean glucose concentrations were significantly lower for curves performed in the authors' hospital than for those performed at home. However, there was no difference between glucose nadirs. For the third curve comparison, the maximum and mean glucose concentrations of hospital curves tended to be lower than those of home curves, but the differences were not significant. For the fourth curve comparison, the maximum and mean glucose concentrations were similar for the hospital and home curves (Fig 3).

Insulin dosage based on blood glucose curves

A total of 38 pairs of blood glucose curves (hospital and home) were analysed to determine whether the two corresponding curves would have led to the same or to a different clinical decision with regard to adjustments of insulin dosage. For 22 pairs, the dosages would have been in agreement (Fig 4A) and for 16 they would have been different. Based on the home curves, in five of 16 cases the insulin dosage would have been lowered, whereas, on the basis of the hospital curves, four would have remained unchanged (Fig 4B) and one would have been increased (Fig 4C). In seven of 16 other cases, the hospital curve would have led to no change, whereas, on the basis of the home curves, the dosage would have been lowered in four cases (Fig 4D) and increased in three (Fig 4E). In the remaining four cases, the insulin dosage would have been increased based on hospital blood glucose curves and left unchanged based on home curves (Fig 4F).

DISCUSSION

When the concept of self-monitoring of blood glucose concentrations in human diabetics was first introduced in 1961, it was largely ignored (Knight and Keen 1961). It was not until the late 1970s that it gained acceptance. Nowadays, self- or home monitoring is an integral part of the management of diabetes mellitus in humans (American Diabetes Association 1996). To the authors' knowledge, this is the first study to show that the monitoring of blood glucose concentrations of diabetic dogs can be performed by their owners at

home. Ten out of 12 (83 per cent) owners of diabetic dogs were willing and able to collect blood from their dog's ear using an automatic lancing device, to measure the blood glucose concentration using a PBGM, and to produce blood glucose curves during a four-month period. Home monitoring was introduced to owners gradually; it was mentioned at the first evaluation, although the procedure was not described. At that time, the owners were encouraged to concentrate on understanding the disease and on the correct injection technique for the administration of insulin. The re-evaluation one week later again focused on the correct injection technique and general problems encountered with the management of their dog's diabetes mellitus.

Home monitoring was introduced three weeks after the first evaluation. It was felt that, by this time, owners had become familiar with the disease and understood the importance of routine determination of blood glucose concentrations. The majority of owners were, by then, interested in determining blood glucose concentrations and curves themselves. In human medicine, it is known that user technique is the major source of error in self-monitoring of blood glucose concentrations. Thus, monitoring of the technique by an expert and frequent practice are of the utmost importance (Skyler and Cohen 1997). For additional practice, owners were asked to determine a single blood glucose concentration at least twice weekly, in addition to the blood glucose curves every three to four weeks, but the former results were not used in this study. The interval of three to four weeks between re-evaluations that was used in this study was about half of that used in other diabetic dogs that were only evaluated in the hospital and not at home.

Frequent re-evaluations helped the authors to ensure that the blood collections and the use of the PBGM were performed correctly, and to answer any questions that arose. It also enabled them to compare blood glucose curves performed at home with those performed in the hospital. At each re-evaluation, owners were encouraged to contact the hospital via telephone when problems or questions arose. At the end of the four-month study, all 10 owners who performed the procedure successfully were very comfortable with home monitoring. All owners kept their PBGMs, and at least once a month they produced a blood glucose curve which was faxed to the authors' clinic and discussed via telephone. The majority of owners learned how to interpret the blood glucose curves during the course of the study, and were able to suggest adjustments in insulin dosage and/or feeding, based on these.

In humans, inadequate blood sample volumes account for approximately half of the procedural errors (Fleming 1994). Preliminary studies indicated that the best method for obtaining capillary blood from the ear of a dog was with an automatic lancing device that created negative pressure after the skin was lanced (Wess and Reusch 2000a). In contrast to other lancing devices, this device produces an adequate volume of blood for use in a PBGM. However, it also caused most of the problems encountered during the initial stages of home monitoring. Owners usually applied too much pressure on the outer pinna against the lancing device, thereby preventing the formation of a sufficiently large blood drop. In the Eurasian dog, the small, stiff and very thick ear, with its large amount of hair, prevented the formation of adequate negative pressure and thus the formation of a blood drop. In this dog, negative pressure was allowed to develop first without lancing the inner ear. This created adequate hyperaemia for the device to be used as normal.

Approximately 50 per cent of owners were able to perform home monitoring without further help. For the remaining owners, telephone advice and/or repeated demonstrations of the technique in the authors' clinic were necessary. As owners became more confident, the number of questions decreased. The dogs tolerated the procedure remarkably well. This was probably because the procedure was not painful. In all of the dogs, the inner ear appeared normal, and lancing sites were barely visible, even after several blood glucose curves had been produced.

The aim of a previous study by Casella and Reusch (2000) using healthy dogs was to identify problems encountered by owners performing home monitoring of blood glucose concentrations. The findings were used in the present study when teaching owners home monitoring; particular attention was paid to the correct formation of negative pressure in producing a blood drop using the lancing device. As a result, owners in this study learned the procedure of home monitoring much more quickly. This illustrates that thorough instruction in the techniques involved in home monitoring is very important. The veterinarian or technician must be familiar with the technique and all potential problems associated with it. Obviously, owners of diabetic dogs are more motivated to master the technique than owners of healthy dogs.

Aside from blood collection, the performance of the PBGM and its correct use are critical for successful home monitoring. Studies in human medicine have shown that the accuracy of PBGMs can vary greatly (Trajanoski and others 1996, Chan and others 1997, Brunner and others 1998). The overall reliability of PBGMs depends on the analytical performance of the instruments, proficiency of the operator, and the quality of the test strips (American Diabetes Association 1996). In the past few years, several groups of investigators have evaluated PBGMs for use in animals (Joseph and others 1987, Link and others 1997, Cohn and others 2000, Wess and Reusch 2000b,c). It is, however, difficult to compare the results of these studies because different types and generations of PBGMs were evaluated and different statistical analyses were used.

In human medicine, error grid analysis has recently proved to be a useful method for assessing blood glucose concentrations, and has gained widespread acceptance

(Clarke and others 1987, Kabadi and others 1994, Brunner and others 1998). With this method, blood glucose concentrations are graphically allocated to five different zones (zones A to E). Measurements in zone A are clinically accurate, those in zone B result in benign errors, and both are clinically acceptable. Measurements in zones C, D and E lead to errors (of different severity) in the treatment of the animal and are thus unacceptable.

Error grid analysis was employed in two veterinary studies which used venous and capillary blood to evaluate different PBGMs, including the one used in this study. All measurements were in zones A and B (Wess and Reusch 2000a,b). For the present study, one of the tested PBGMs (Wess and Reusch 2000b) that was simple to use and could be easily placed on the dog's ear was chosen to minimise problems for owners. The Glucometer Elite has no buttons to press, turns on automatically when the test strip is inserted, and requires only a small amount of blood (2 µl), which is automatically aspirated into the reaction chamber after contact with the test strip. (The measurement range of the strip is 11·2 to 33·3 mmol/litre; the result is displayed after 30 seconds and the last 20 readings are stored. These readings are useful in evaluating the owners' ability to correctly read the display.) There are, however, two important points to remember when using this PBGM: when an inadequate volume of blood is used, the acoustic tone that normally signals the end of the measurement still sounds, but the result is incorrect (too low) (Wess and Reusch 2000b); and, similar to all PBGMs, the measurements of the Glucometer Elite deviate slightly from those of a reference method. In contrast to other PBGM measurements, which variably over- or underestimate reference values, the Glucometer Elite tends to consistently underestimate glucose concentrations (Wess and Reusch 2000a,b). This is viewed as an advantage because the errors are more predictable.

Previously published reference values for blood glucose concentrations in healthy dogs and blood glucose concentrations and curves in diabetic dogs have presumably been determined in clinics or hospitals, and not at home. These values may not accurately reflect the actual concentrations because of the effects of stress due to transport to the clinic and being in an unfamiliar environment, and because animals may have a reduced appetite in hospital which affects blood glucose concentrations. In the present study, owners performed four blood glucose curves at home over a four-month period. Within one week of producing each curve at home, a blood glucose curve was also produced in the authors' hospital. Surprisingly, in the first two curve comparisons, the maximum and mean glucose concentrations of the hospital curves were significantly lower than those of the home curves. In the third curve comparison, there was still a difference but it was not significant and by the fourth curve comparison, the hospital and home curves were almost identical. The authors had assumed that, due to stress and reduced activity in the hospital, the blood glucose concentrations would have been higher than those measured at home. Reduced appetite thus appears to be the most probable explanation. Although each owner brought their dog's usual food to the hospital, most ate only a portion of their normal ration while in the hospital. This changed by the time of the third and fourth hospital blood glucose curves, when the dogs were accustomed to the hospital and staff, and appetite remained normal. It was unlikely that the differences between hospital and home blood glucose curves were attributable to technical errors made by owners. An inadequate blood volume or incorrect placement of the blood drop on the test strip would both result in inaccurate, low blood glucose measurements; this would have led to lower home measurements than hospital measurements.

In addition to comparing the home and hospital curves statistically, the authors also compared the potential treatment decisions based on the curve results from each dog. In 42 per cent of cases, treatment decisions based on hospital curves differed from those of home curves. However, in only 3 per cent would the treatment decisions have been reversed (increase versus decrease of insulin dosage). In the remaining 39 per cent of cases, the treatment decisions, although different, would have been of lesser consequence (no change versus increase or decrease of insulin dosage). The authors do not know whether these differences were attributable to home monitoring. The reproducibility of glucose curves is difficult to assess because the glucose concentration may vary from day to day (Feldman and Nelson 1996, Fleeman and Rand 2001). The latter study, however, were performed in a hospital. Further investigation is necessary to determine whether the reproducibility of blood glucose curves produced at home is in fact better than for those produced in a hospital.

In this study, treatment changes were usually based on the results of home blood glucose curves. From the start of the study, the authors felt that home blood glucose curves corresponded better with clinical signs and fructosamine concentrations than did hospital curves. At the end of the study, 10 owners (including the two that did not monitor their dogs at home) felt that the results of treatment were very good, and two thought they were satisfactory to good. Whether this high rate of success was associated with home monitoring remains unknown. Further studies are underway at the authors' clinic to determine whether management of diabetes mellitus in dogs is improved when home monitoring is used. The greatest advantage of home monitoring is that blood glucose concentration can be measured at any time. In questionable cases, a number of individual blood glucose measurements or blood glucose curves can be generated. In addition, blood glucose curves performed at home are likely to more accurately reflect the efficacy of the insulin dosage than those performed in a hospital.

Conclusions

The results of this study indicate that owners of diabetic dogs are willing and able to perform long-term home monitoring of their pet's blood glucose concentrations. A thorough explanation and demonstration to owners of the home monitoring techniques is important to minimise technical problems. Periodic evaluations of owner technique are recommended. The reasons for measuring blood glucose concentrations should be explicitly explained to owners, to avoid confusion and to provide a better understanding of the management of their dog's diabetes mellitus.

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Inhaltsverzeichnis

Home monitoring in cats with diabetes mellitus: evaluation of differences between blood glucose concentrations measured at home and in the clinic

Home-monitoring in cats with diabetes mellitus: evaluation of differences between blood glucose concentrations measured at home and in the hospital.

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Summary

Home-monitoring of blood glucose concentrations by collecting capillary blood from the ear of their pet using a lancing device and a portable blood glucose meter has recently been introduced to owners. The objectives of this study were to investigate the feasibility of home-monitoring of blood glucose in diabetic cats by owners on a long-term basis, the problems encountered and to compare glucose concentrations at home with those measured in the hospital. Twelve of 15 selected cat owners were able to generate glucose curves over the study period of 4 months. Most problems were related to restraining the cat, generating negative pressure with the lancing device and producing a blood drop. In the majority of cases, these problems could be resolved during the study. Blood glucose concentrations in the clinic tended to be lower than at home; some of the differences were significant. Overall, in 38% of cases, treatment based on hospital curves would have been different from that based on home curves. It is assumed that glucose measurements at home are more reliable than those measured in the hospital and that home monitoring helps to prevent wrong treatment decisions.

Introduction

Serial blood glucose curves (BGCs) are necessary to assess insulin efficacy, glucose nadir, time of peak insulin effect, duration of the insulin effect, and degree of fluctuations in blood glucose (BG) concentrations. Blood glucose curves are also required to recognise the Somogyi phenomenon (Feldman & Nelson 1996). Until recently, the vast majority of BGCs were performed in the hospital because most pet owners are unable to collect blood samples by venipuncture. However, a variety of problems are associated with the determination of BGCs in hospitalised patients. The process is time consuming and relatively expensive and therefore, is not performed as frequently as required. Stress or lack of food intake can markedly influence BG concentrations. Cats in particular are sensitive to stress caused by an unfamiliar environment or by veterinary manipulation. Therefore, especially in diabetic cats, in-hospital BGCs can be difficult to interpret or may even be useless.

In human medicine, it is standard procedure for diabetics to determine their own blood glucose concentrations with a portable blood glucose meter (PBGM). Blood is usually collected from a fingertip using a lancing device. This so called self-monitoring has become an integral part of the management of diabetes mellitus in humans (Cohen & Zimmet 1980, Bergman & Felig 1984, American Diabetes Association 1996, 1998, Foster et al 1999).

Several recent studies have shown that collection of capillary blood using a lancing device is possible in dogs and cats, and glucose concentrations determined using a PBGM and capillary blood from the ear are in agreement with those of venous blood (Wess & Reusch, 2000a, Thompson et al, 2002). Evaluation of various PBGMs showed that their accuracy and reliability were sufficient for the purpose of home-monitoring of diabetic dogs and cats. (Wess & Reusch 2000 b, c). A number of problems, mostly technical in nature, can arise during home-monitoring. However, with experience many pet owners overcome these difficulties and perform correct measurements (Casella & Reusch 2000, Casella et al 2002). A recent study performed over several months in diabetic dogs revealed that in 42% of glucose curves (total of 38 pairs), treatment decisions based on BGCs generated in the hospital differed from those generated by the

owners at home. In 3% of cases, treatment decisions based on in-hospital BGCs completely contradicted those based on BGCs determined at home (Casella et al, accepted 2003).

To the authors' knowledge, there are no studies on home-monitoring of blood glucose concentrations of diabetic cats by their owners. Therefore, the objectives of this study were a) to determine whether owners of diabetic cats are willing and able to perform home-monitoring on a long-term basis, b) to determine the types of possible problems encountered and c) to compare BGCs generated in the hospital with those generated at home by the owner, using the same technique.

Materials and methods

Selection of cats

This prospective study was conducted during the years 1999 and 2000 at the Clinic of Small Animal Internal Medicine, University of Zurich, Switzerland. Cats with diabetes mellitus were included in the study if their owners were willing to learn home-monitoring and to return to our clinic for 6 re-evaluations of their cats over a 16-week period.

Diagnosis of diabetes mellitus was based on characteristic clinical signs, fasting hyperglycemia and elevated serum fructosamine (>340 μmol/l). Fifteen cats with a median age of 11 years (range 5 to 16 years) were included in the study. In 13 cats, diabetes mellitus was diagnosed at our clinic. One cat had been treated with insulin for 3 days and one other for 2 months by the referring veterinarian prior to the study. There were four spayed female and 11 castrated male cats. Breeds included domestic shorthair cats (n=14) and one Main Coon. Twelve were indoor cats and three were allowed to go outside. None of the owners was familiar with blood collection prior to the study. Informed owner consent was obtained in all cases.

Study design

A thorough physical examination, complete blood count, biochemical profile (including fructosamine and total T4) and urinanalysis were performed in all cats. Further examinations were performed when indicated. Cats received an intermediate-acting insulin (Caninsulin®, Intervet, Boxmeer, the Netherlands) at a dosage of 0.25 IU/kg when fasting BG was <20 mmol/l SC, BID, and 0.5 IU/kg, SC, BID, when fasting BG was >20 mmol/l. The majority of cats remained in our clinic for 3 days. Blood glucose concentrations were determined before and every 3 hours after administration of insulin for a 12-hour period (5 measurements). The dosage of insulin was adjusted only when hypoglycemia occurred (BG concentration <3 mmol/l). Six cats that had diabetic ketoacidosis and one cat with hypoglycaemia due to insulin over dosage at the time of admission underwent intensive treatment; after stabilisation they were treated as described above. At discharge, owners received detailed information on various aspects of diabetes mellitus and were instructed on how to inject insulin. Also, the concept of home-monitoring was introduced to the owner for the first time.

Re-evaluations were scheduled 1, 3, 6, 9, 12, and 16 weeks after the first evaluation and included a detailed updated history, physical examination and measurement of haematocrit and concentrations of serum fructosamine, albumin and total protein. A blood glucose curve was obtained by measuring BG concentration before and every 2 hours after administration of insulin for a 12-hour period (7 measurements).

At the second re-evaluation , each owner was taught the technique of home-monitoring. This process took a minimum of 30 minutes and consisted of repeated demonstrations. The owners then performed the technique once or twice on their pet. Each owner was also taught how to calibrate the PBGM, how to check its accuracy using the control strip and how to record BG concentrations on prepared forms.

Owners received written instructions, which included pictures of the home monitoring technique, a PBGM, test strips, a lancing device, a form to record BG measurements and a questionnaire. They were asked to perform a blood glucose curve at home within 1 week prior to the next re-evaluation. Blood glucose concentrations were to be determined before and every 2 hours after administration of insulin for a 12-hour period. Owners were also asked to fill in a questionnaire after each BGC (Casella et al

2002). At the third re-evaluation (6 weeks after the first evaluation), a veterinarian (MC) evaluated and, if necessary, corrected the owner's technique of capillary blood collection. When required, other aspects of the home-monitoring technique were also discussed at this time. Insulin dosage was adjusted based on the glucose nadir: when the nadir was <5 mmol/l, from 5 to <9 mmol/l, or ≥9 mmol/l, the insulin dosage was decreased (1 IU/cat), remained unchanged or was increased (1 IU/cat), respectively.

Owners performed a total of 4 BGCs, which were referred to as home curves. A BGC was performed at our clinic within 1 week after each of the home curves; these curves were referred to as hospital curves. Each of the 4 home curves was compared to the corresponding hospital curve. The comparisons were referred to as the first-curve comparison (fifth and sixth weeks after first evaluation), second-curve comparison (eighth and ninth weeks after first evaluation), third-curve comparison (11th and 12th weeks after first evaluation) and fourth-curve comparison (15th and 16th weeks after first evaluation). The dosage of insulin administered was identical for each pair of corresponding curves.

Equipment

The PBGM and lancing device used in this study were the Glucometer Elite® and the Microlet Vaculance® (both from Bayer Diagnostics, Zurich, Switzerland).

Collection of capillary blood and measurement of blood glucose concentration

Capillary blood was collected from the inner pinna using the lancing device. Blood glucose concentrations were measured using the PBGM. The technique was performed as previously described (Wess & Reusch 2000a, Reusch et al 2001, Casella et al, 2002, 2003). For all blood glucose measurements (hospital and home), the same blood collecting technique and the same type of PBGM were used (Fig 1).

Data analysis

A descriptive data analysis was used for describing technical problems encountered during blood collection. The general condition of each cat and clinical variables were used to assess the efficacy of therapy. A cat was considered stable if it was healthy and

interactive at home, had a normal appetite, normal water intake and a stable body weight and if the BG concentrations during the day were between 4.5 and 26 mmol/l. A difference of 50 μmol/l between the serum fructosamine concentration at the beginning and end of the study was defined as clinically relevant, e.g. relevant increase or relevant decrease (Reusch et al 1995).

Ranges and medians were used to describe the variables age and weight. Blood glucose curves that consisted of at least five measurements were compared by analysis of variance for repeated measures (Stat View 5.0, SAS Institute, Wangen, Switzerland). Differences were considered significant at $P<0.05$. Box-and-whisker plots were used for graphical representation of glucose concentrations. The horizontal lines of the box represent, from bottom to top, the 25th, 50th (median) and the 75th percentiles. The ends of the whiskers represent the 10th and the 90th percentiles. Outlying data points are represented by open circles.

Results

Symptoms and serum fructosamine concentrations

In all cats, symptoms of diabetes mellitus completely or partially subsided during treatment. At the end of the study, five cats had no clinical signs of diabetes mellitus and were considered to be well stabilized. In seven other cats, water intake was close to normal or fluctuated from day to day and they were considered to be satisfactorily to well stabilized. Two other cats were not stable despite improvement in symptoms; in both, water intake remained elevated. Serum fructosamine concentrations decreased during treatment in eight cats, remained unchanged in four, and increased in three cats.

Feasibility of home monitoring

Twelve of 15 owners were able to determine BG concentrations. Seven of them completed all four BGCs. The other five owners encountered problems with blood collection: two completed only the last three of four BGCs, two only the last two BGCs and one owner performed only the first, third and fourth BGC. Three of 15 owners were

unable to perform any BG measurements because their cats did not tolerate the procedure.

Problems encountered initially included: producing negative pressure with the lancing device (11/12), producing a blood drop (10/12), restraining the cat (8/12), absorption of the blood drop (4/12) and correct use of the test strips (2/12) and the PBGM (2/12). At the end of the study, there were still problems involving restraint of the cat (8/12), production of a blood drop (3/12) and the generation of negative pressure using the lancing device (2/12). Of the 12 owners who completed the study, home-monitoring at the time of the first-curve comparison was considered not feasible or difficult by four, mostly straightforward by three and straightforward by one. At the end of the study, home monitoring was considered difficult by only one owner, mostly straightforward by six and straightforward by five. Ten of the 12 owners performed BG measurements without help and two owners always required another person for help. Of the 12 cats, two tolerated the procedure very well from the start of the study, five became accustomed to the procedure during the first time and five continued to encounter some problems (three did not tolerate the procedure well for the first BGC). At the end of the study, four tolerated the procedure very well, six became accustomed to the procedure after the first or second blood sample of every BGC and two continued to cause problems during the collection of blood.

In the clinic, two of 12 cats were aggressive making completion of all BGCs difficult. In one, the first two BGCs and in the other, the last two BGCs were not performed.

Comparison of home and hospital blood glucose curves

A total of four comparisons between home and hospital BGCs were made. The maximum (±SD) BG concentrations (mmol/l) in BGCs performed in the clinic and at home, respectively, were 23.8 ± 3.6 and 26.6 ± 2.5 for the first curve comparison, 25.1 ± 5.7 and 25.4 ± 7 for the second curve comparison, 22.9 ± 6.4 and 22.0 ± 8.3 for the third curve comparison, and 21.2 ± 6.8 and 22.7 ± 6.7 for the fourth curve comparison. The mean (±SD) glucose concentrations (mmo/l) of curves performed in the clinic and at home, respectively, were 19.1 ± 3.9 and 29.3 ± 2.4 for the first curve comparison, 17.6 ± 6.2 and

17.8 ± 6.4 for the second curve comparison, 13.7 ± 6.2 and 15.9 ± 6.9 for the third curve comparison, and 13.4 ± 6 and 16.8 ± 6.3 for the fourth curve comparison (Fig2A). The nadirs (±SD) of the hospital and home curves, respectively, were 14.8 ± 4.8 and 13.8 ± 4, 12.2 ± 5.6 and 10.6 ± 6.6, 7.5 ± 6 and 10.5 ± 6, and 6.7 ± 5 and 11.2 ± 6.1 for the first, second, third and fourth curve comparisons, respectively (Fig. 2B).

The minimum glucose concentrations in the third and fourth curve comparisons and the mean glucose concentration in the fourth curve comparison were significantly lower for curves performed in the hospital than for those performed at home. There was no difference between maximum glucose concentrations measured in the hospital and at home.

Insulin dosage based on blood glucose curves

A total of 37 pairs of BGCs (hospital and home) were analysed to determine whether the two corresponding curves would have led to a different clinical decision with regard to adjustments of insulin dosage. Of 37 hospital curves, 29 were complete (all seven BG measurements), six had six BG measurements and two had five BG measurements. Of 37 home curves, 32 were complete (all seven BG measurements) and five had six BG measurements. Decisions regarding insulin dosage would have been in agreement in 23 pairs of BGCs (Fig. 3A) and would have differed in 14. Based on the results of home BGCs, no change in insulin dosage would have been instituted in nine of 14 cats (Fig 3 B, F), whereas on the basis of hospital curves, the insulin dosage would have been decreased in six cats (Fig. 3 B) and increased in 3 (Fig. 3F). In four other cases, the insulin dosage would have been increased based on home BGCs (Fig. 3 C+E), whereas on the basis of hospital BGCs, the insulin dosage would have remained unchanged in two cats (Fig 3E) and decreased in two (Fig. 3C). In the one remaining case, the insulin dosage would have been decreased based on the home BGC and increased based on the hospital BGC (Fig. 3G).

Discussion

80% (12 of 15) of the owners of diabetic cats in our study were willing and able to perform a series of BGCs at home over a period of four months. In a previous study, only 43% (3 of 7) of owners of healthy cats were able to perform the same tasks during a shorter study period (Casella et al 2002). Possibly, owners of ill cats are more motivated to overcome the problems associated with home-monitoring with the hope that their pet will benefit from their efforts. For example, many owners devised strategies for easier restraint of their cat and reported that the cat tolerated blood collection better when placed in a favourite spot, such as a windowsill or bed or in a confined area such as a sink. The present study lasted longer and possibly gave owners more time to become proficient at the technique of home-monitoring. Furthermore, in comparison to the healthy cats, the diabetic cats seemed to cooperate substantially better during the procedure of blood collection. This may be because the diabetic cats were older than the healthy cats and with the exception of one, were exclusively indoor cats.

The success of home-monitoring hinges greatly on careful preparation and instruction of the owner. The technique of home-monitoring was first introduced to all owners three weeks after the initiation of treatment in our clinic. This time frame allowed owners to become familiar with the disease and with administration of insulin. Re-assessments were carried out frequently (every three or four weeks) so that the owners' technique could be evaluated often and corrected when necessary.

Three of 12 owners were immediately able to generate BGCs at home. Technical errors were corrected via telephone for two owners. However, additional demonstrations of the technique in our clinic were necessary for seven owners. In human medicine, the importance of patient education with repeated demonstrations and observation of patient technique is emphasised in a study of The National Steering Committee for Quality Assurance in Capillary Blood Glucose Monitoring (1993). It has been shown that most errors in self-monitoring of blood glucose concentration are associated with blood collection or use of the PBGM (Fleming 1994). It is also important to minimise any technical difficulties for pet owners. In the present study, the Glucometer Elite® was selected as the easiest PBGM on the market to operate: it has no buttons to press, turns on

automatically when the test strip is inserted and requires only a small amount of blood (2 μl), which is automatically aspirated into the reaction chamber after contacting the test strip. Studies in humans have shown that the accuracy of PBGMs can vary greatly (Brunner et al 1998, Trajanoski et al 1996, Chan et al 1997). In the past few years, several groups evaluated PBGMs for use in animals using a variety of different statistical procedures (Joseph et al 1987, Link et al 1997, Cohn et al 2000, Wess & Reusch 2000b,c). In human medicine, error grid analysis has gained widespread acceptance for the assessment of blood glucose measurements (Clarke et al 1987, Kabadi et al 1994, Brunner et al 1998). Two recent veterinary studies that used error grid analysis demonstrated that glucose measurements of canine and feline blood samples using different PBGMs were in clinically acceptable ranges (Wess & Reusch 2000b,c). In contrast to other PBGMs, which over- or underestimated glucose concentrations, the one used in the present study consistently underestimated blood glucose concentrations (Wess & Reusch 2000b,c). This is considered an advantage because the errors are more predictable. Because collection of blood via venipuncture is beyond the scope of an average pet owner, a method for collection of capillary blood using a special lancing device (Microlet Vaculance®) was recently developed. This device creates a negative pressure, which facilitates collection of an adequate amount of blood from the ear of cats and dogs (Wess & Reusch 2000a). An important prerequisite for blood collection is correct handling of the lancing device so that it actually creates a vacuum. This can be difficult and is linked to most of the technical problems (Casella & Reusch 2000, Casella et al 2002). In our experience, this problem can be overcome by repeated demonstrations and practice.

Interestingly, the minimum glucose concentrations in the third- and fourth-curve comparisons and the mean glucose concentration in the fourth-curve comparison were significantly lower for hospital curves. In fact, we had assumed that due to stress caused by an unfamiliar environment, veterinary manipulation and reduced physical activity during the stay in the clinic, the BG concentrations would be elevated. Cats are considered particularly sensitive to stress (Leidinger et al 1989, Opitz 1990, Feldman & Nelson 1996). However, a plausible reason for lower BG values in hospitalised patients is that they frequently refuse to eat. In a similar study of diabetic dogs, a decrease in food

intake was believed to be the most likely explanation for lower BG concentrations in hospitalised dogs compared to dogs evaluated at home (Casella et al 2003). It is unlikely that the differences were attributable to technical errors made by owners at home, because an inadequate amount of blood would have resulted in an erroneous low BG measurement (Wess & Reusch 2000b, c). We do not know why there was no such difference between the BGCs in the first two curve comparisons, but we hypothesise that it was due to stress-related hyperglycaemia overriding a decrease of BG due to lack of food intake at the beginning of the study in cats in the clinic. During the course of study, the stress caused by the blood collection may have diminished as cats became accustomed to the procedure, although not to the point where they felt comfortable enough to eat. However, it is impossible to determine the role of stress in this study. Physiological stress is difficult to define in animals. Recently, a study attempted to characterise the changes in BGCs in cats exposed to an acute stressor and to determine the associations between BG and behavioural indicators of stress in stress hyperglycaemia (Rand et al 2002). It was demonstrated that there is a strong relationship between increased BG and fear responses of cats and that the nature of the stressor influences the severity of hyperglycaemia. That study, however, was performed in healthy cats, and it is currently not known whether the findings also apply to sick or diabetic cats.

In addition to comparing home and hospital curves statistically, we also compared the potential treatment decisions based on BGCs of each cat. In 14/37 (38 per cent) of the cases (case = one pair of BGCs, treatment decisions based on hospital curves differed from those of home curves; in three cases, the treatment decisions would have been completely contrary and in the remaining 11 cases, they would have differed, although with little clinical consequence. In ten of 14 cases, the insulin dosage based on the hospital curve would have been lower than that based on the home curve. We do not know whether these differences were attributable to home-monitoring. Blood glucose curves are known to vary from day to day (Feldman & Nelson 1996). Similarly, Fleeman & Rand (2003) reported that in diabetic dogs, BGCs determined in the clinic on successive days varied widely. Studies are currently underway in our clinic to compare the reproducibility of BGCs performed at home and in the clinic.

In the present study, the insulin dosage chosen was based largely on the results of home BGCs. We feel that the home environment is the least stressful and that BGCs performed there reflect the glycaemic status better than those performed in the clinic. Therefore, home BGCs may allow for a better control of the disease. Another advantage is that home curves can be carried out as frequently as required. In complicated cases, more than one BGC can be performed at home before a decision is made concerning therapy.

The results of this study indicate that owners of diabetic cats are willing and able to perform long-term monitoring of BG concentrations. At the end of the study, the majority of owners could not only evaluate the results of testing but also dose the insulin correctly. All 12 owners involved in this study elected to keep the PBGM. They communicated with the clinic on a regular basis, and presently, discuss treatment based on home BGCs via telephone or fax at least once a month. This built a close relation between client and veterinarian and provided a good basis for successful control and treatment of the disease. Periodic evaluations of the owners' technique are required and the targeted blood glucose concentrations should be explicitly defined to avoid confusion and to provide a better understanding of the management goals.

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Legends to figures

Figure 1

Capillary blood sampling from the pinna of a cat by use of a lancing device (Microlet Vaculance®)

Figure 2

(A) Comparison of mean blood glucose concentrations of home and hospital blood glucose curves of 12 cats with diabetes mellitus.
(B) Comparison of glucose nadirs of home and hospital blood glucose curves of 12 cats with diabetes mellitus.

The mean blood glucose concentrations of the fourth hospital curve and the minimal blood glucose concentrations of the third and fourth hospital curves were significantly lower compared to the corresponding home curves.

blood glucose concentrations determined in the clinic = black; at home = stippled
* $P<0.05$

Figure 3

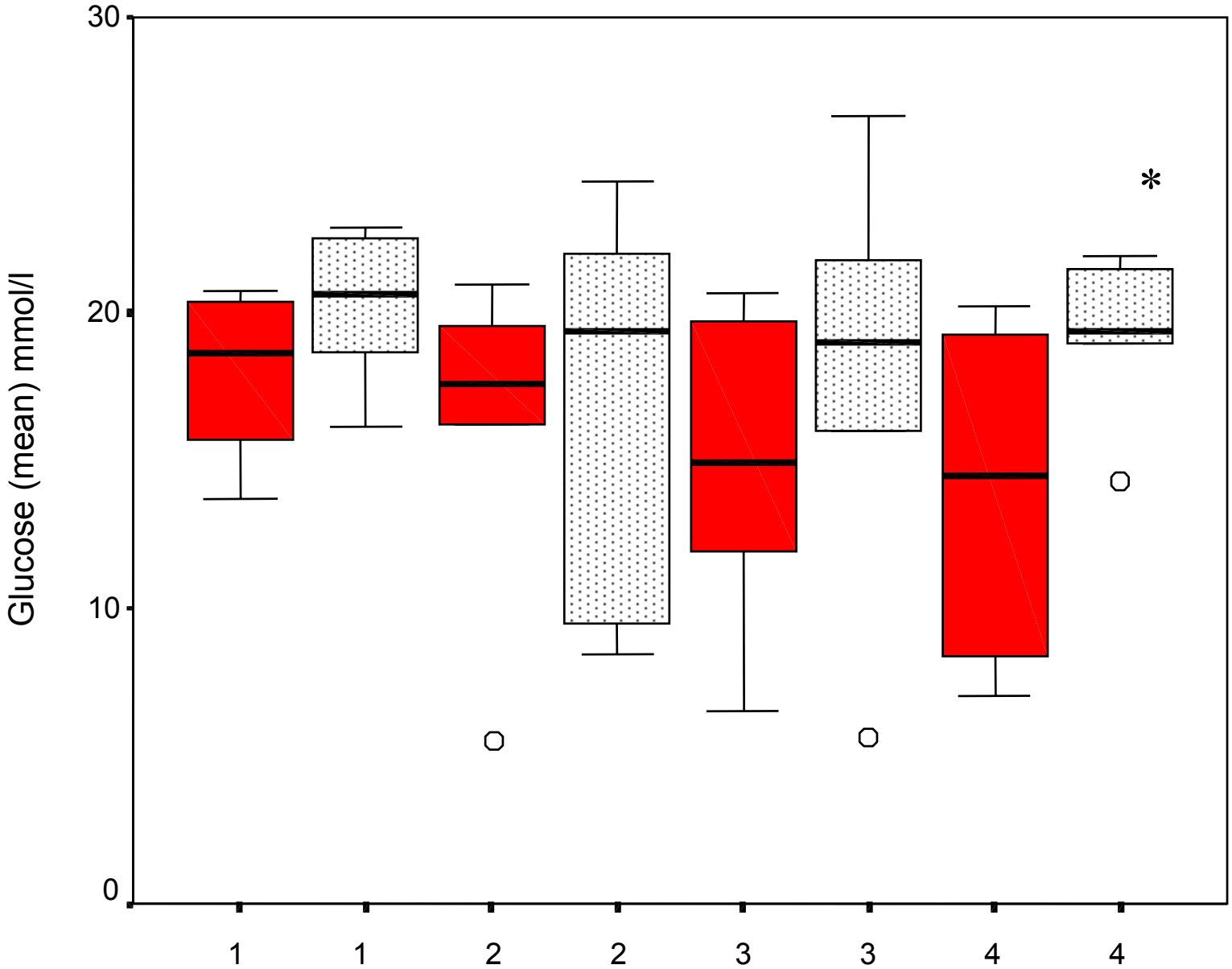
Graphic representation of the glucose nadirs for all blood glucose comparisons. The x-axis represents values from hospital curves and the y-axis represents values from home curves. In 23 of 37 blood glucose pairs, the decisions regarding treatment were in agreement (zone A). In 14 of 37 pairs, the decision regarding treatment differed in one of five different ways:
Zone B; hospital curve: decrease insulin; home curve: insulin unchanged
Zone C; hospital curve: decrease insulin; home curve: increase insulin
Zone D; hospital curve: insulin unchanged; home curve: decrease insulin
Zone E; hospital curve: insulin unchanged; home curve: increase insulin
Zone F; home curve: increase insulin; home curve: insulin unchanged

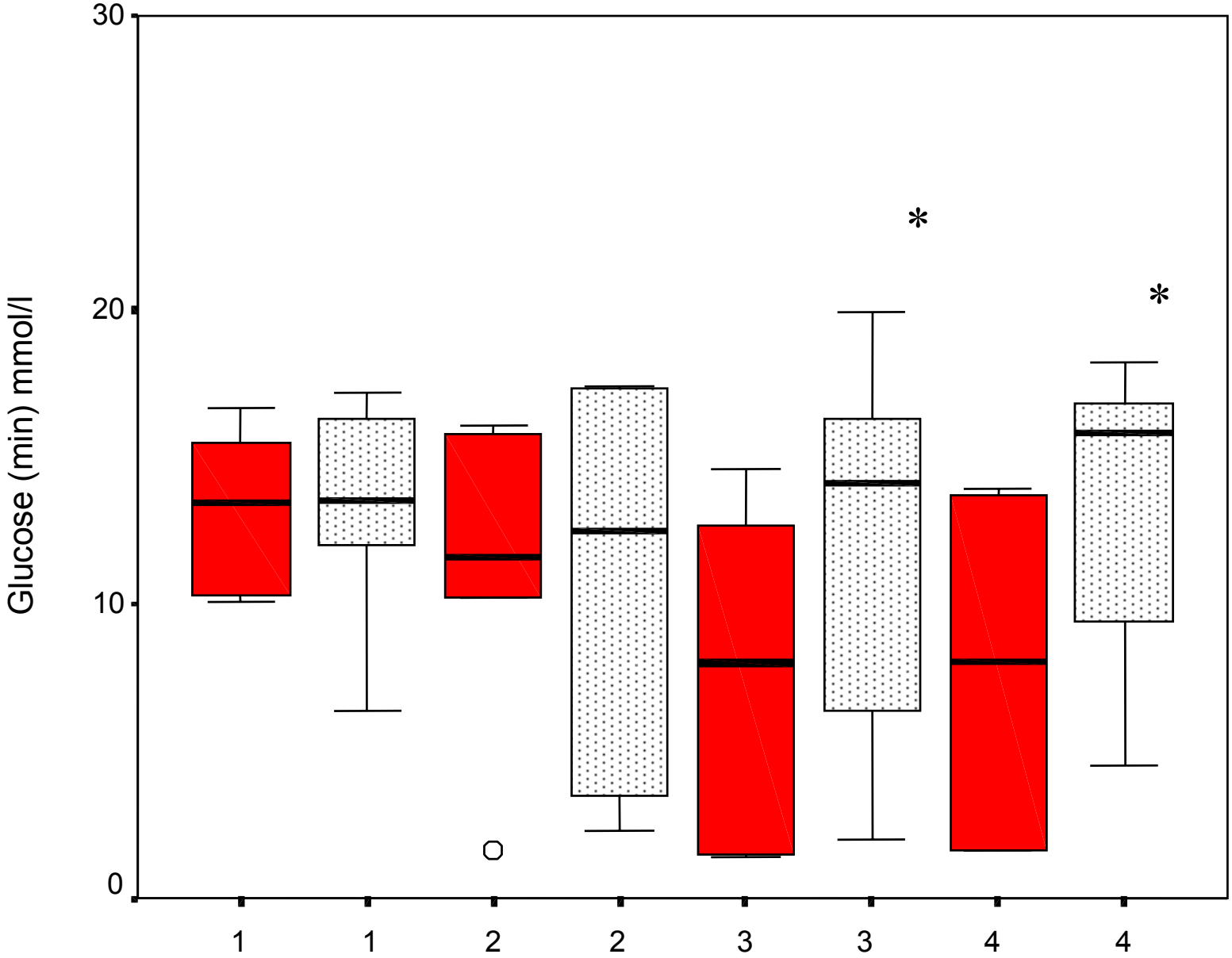
Figure 4

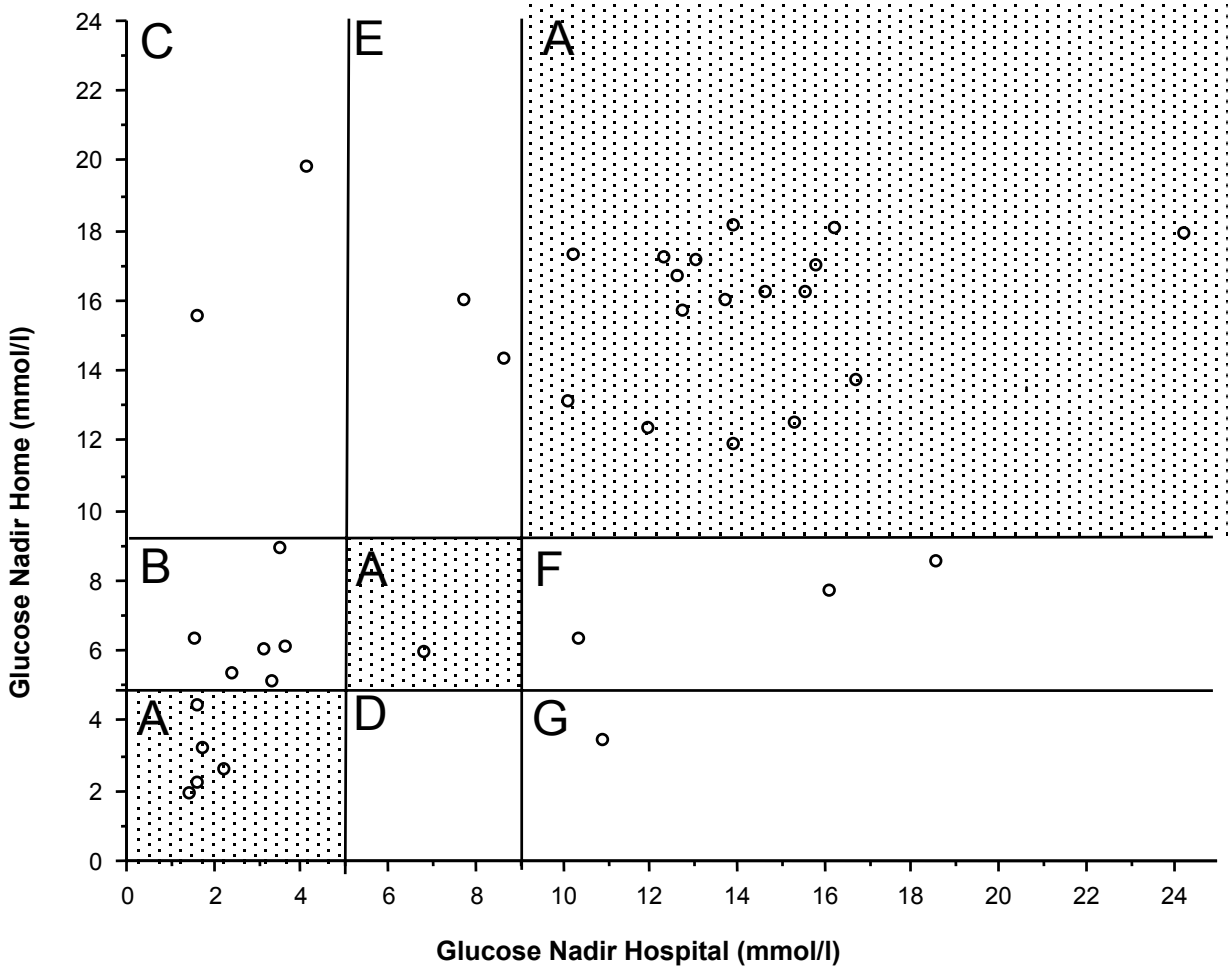
Two blood glucose curves (BGCs), generated either at home (broken line) or in the clinic (solid line) in a 7-year-old, castrated male, domestic shorthair cat. For each BGC, the blood glucose concentration was measured before and every 2 hours after administration of insulin during a 12-hour period for a total of 7 measurements. The two BGCs, generated within one day of each other, differ.

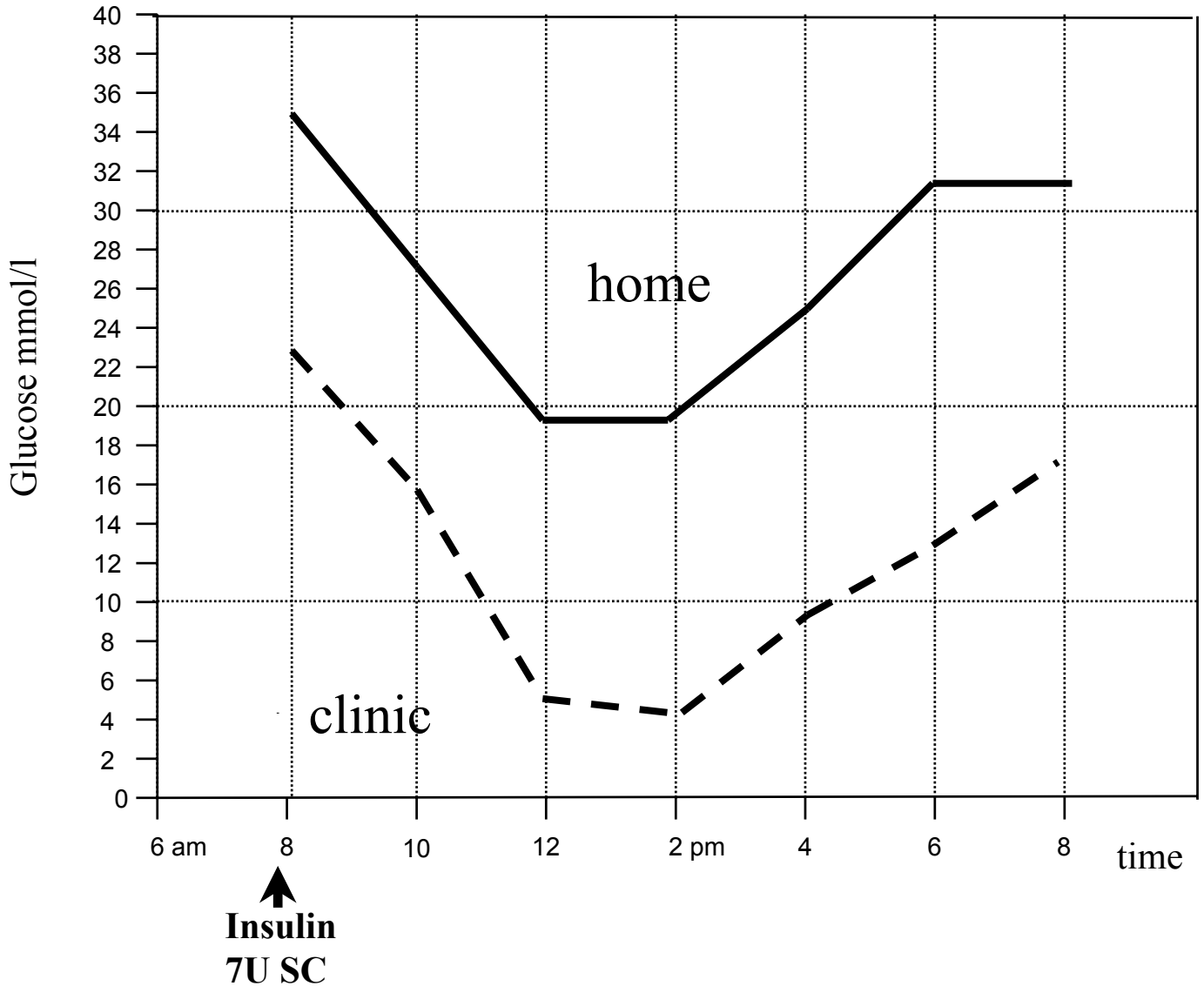
(A) Third re-evaluation. The cat is on 7 IU Caninsulin BID and still showed polydipsia and polyuria. The home BGC has a nadir of 19.9 mmol/l, which is too high, and thus, an increase in the insulin dosage would be advised. The hospital BGC has a nadir of 4.1 mmol/l, which is considered borderline, and a reduction in the insulin dosage might be advised. The final decision was based on the home curve and the insulin dosage was increased to 9 IU, BID.

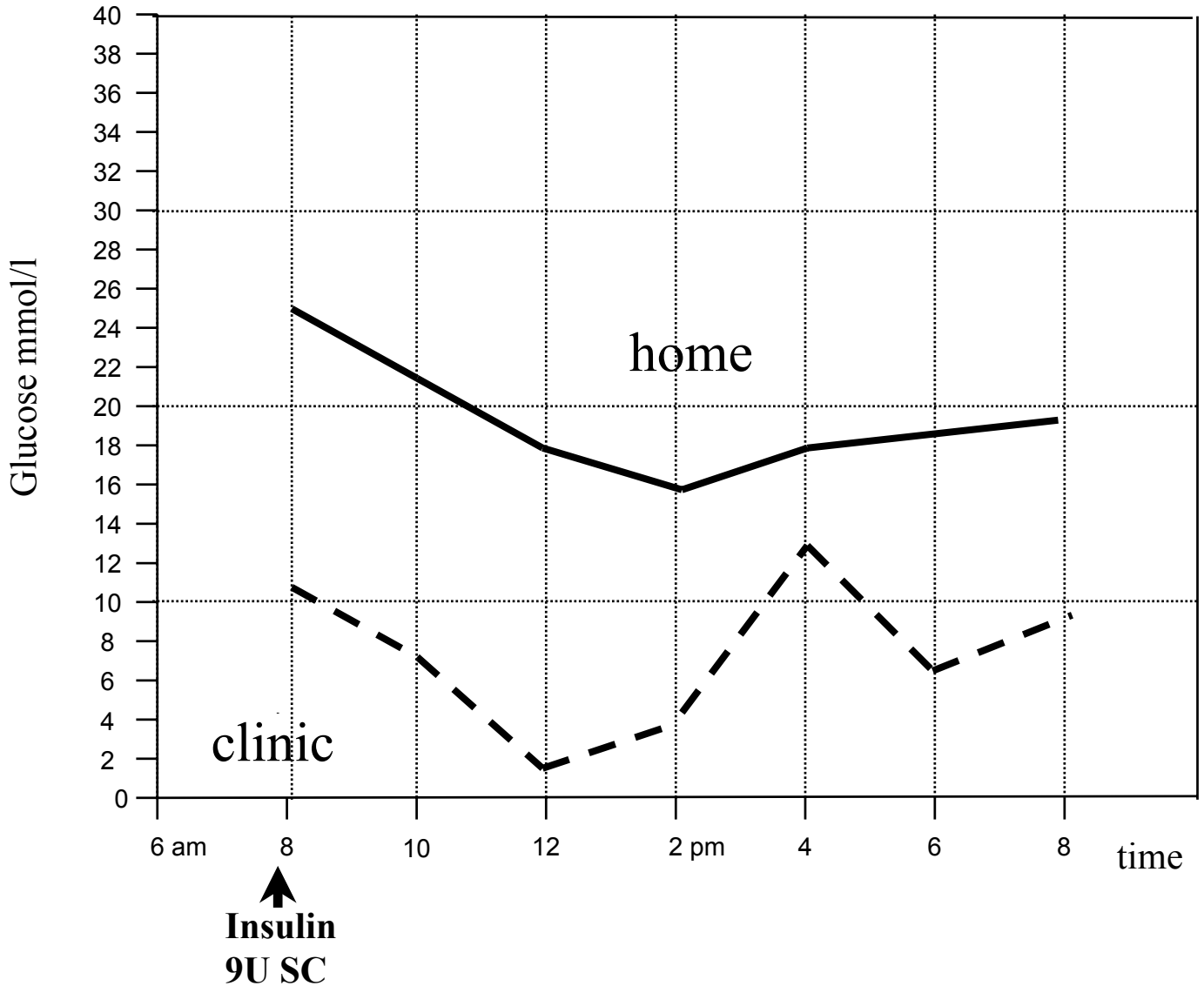
(B) Forth re-evaluation. The cat is on 9 IU Caninsulin BID. Polydipsia and polyuria are still present but have improved. The home BGC had a nadir of 15.6 mmol/l and the hospital BGC a nadir of 1.6 mmol/l. Based on the hospital and home curves, the insulin dosage would be reduced and increased, respectively. The insulin dosage was kept unchanged and the owner was asked to generate another BGC a week later. The low glucose nadirs in the hospital BGC were attributed to decreased food intake during hospitalisation. The home BGC one week later (not shown) had again a nadir >9 mmol/l and the owner increased the insulin dosage to 10 IU, BID. Since then the cat is doing well and clinical signs have normalized.


Glucose (mean) mmol/l
30
20
10
0
1
1
2
2
3
3
4
4


Glucose (min) mmol/l
30
20
10
0
1
1
2
2
3
3
4
4


C
E
A
B
A
F
A
D
G
Glucose Nadir Home (mmol/l)
Glucose Nadir Hospital (mmol/l)
0
2
4
6
8
10
12
14
16
18
20
22
24


Glucose mmol/l
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
home
clinic
6 am
8
10
12
2 pm
4
6
8
time
Insulin
7U SC


Glucose mmol/l
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
home
clinic
6 am
8
10
12
2 pm
4
6
8
time
Insulin
9U SC

CURRICULUM VITAE

Martina Casella

Geboren

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Carona/Tessin

Ausbildung

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Anstellungen

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Gegenwärtigen Anstellung

Tierärztin Praxis Dr. Togni in Massagno/TI